ACCOUNTING TIMES SERIES

AS EVIDENCE OF UNIVERSITY STRATEGY AND STRUCTURE

Jarrod W. Wilcox
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ABSTRACT

    The strategic management of large organizations is impeded by the
massive complexities to be analyzed. New approaches are needed to make
possible a sharper focus on the key variables. The Treasurer's Report
of the Massachusetts Institute of Technology offers a wealth of data
amenable to statistical analysis. This paper illustrates multivariate
methods for using these data to obtain evidence as to an organization's
structure and modes of response to environmental disturbances.
    Because of the ready availability of financial data the study
emphasizes problems largely financial in character.

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Section A. Introduction

The purpose of this paper is to illustrate the application of explicit statistical analysis to problems of analyzing organizational structure and strategic response to environmental uncertainties. After a brief discussion of relevant theory, an examination is made of a specific case, the Massachusetts Institute of Technology during the period 1950-1970. The results of factor analysis and cluster analysis of year-to-year changes in M.I.T. financial figures are reported. Some implications of interest to M.I.T.'s policy-makers are noted. Finally, the strengths and weaknesses of the methods employed are considered in the light of the results of the study.

Administrative Use of Statistical Methods for Planning and Control

The increased feasibility made possible by computers for extensive statistical analysis of data from the management information systems of large organizations has not yet been much exploited.[1] Many routine intelligence activities for more effective managerial planning and control could be carried out using existing data. There exists the popular view that statistical methods, indeed quantitative methods in general, are relatively inapplicable to problems of designing changes in major policy and organizational structure. Therefore, a major motivation of this study is to find out more about to what extent these problems can usefully be attacked through statistical analysis.

Section B. Background Theory

One of the most common drawbacks to the use of statistics in modeling causal systems is the lack of any guiding framework to narrow the focus of

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[1] See Zannetos [1968].

facts to be considered. In this section, the reader is informally introduced to the theoretical viewpoint of the study. This introduction is necessarily brief. However, it will serve to provide some delimiters on the direction of the statistical analysis presented later.

Policies Underlying Partly Repetitive Decision-Making

The assumptions underlying managerial decisions are always based on someone's observation of past experience. In some sense, therefore, decisions are almost always repetitive in many aspects. Thus, it is useful to analyze a series or stream of decisions based on the same underlying assumptions or policy. When analyzing organizational decisions, an additional complication must be kept in mind. Organizational decisions very often represent a sequential aggregation of individual decisions.

In order to improve the effectiveness of these decisions, it is often critical to determine the assumptions and aggregating mechanisms which underly them.[2] Unfortunately, in large organizations, no one person may be aware of more than a few of the causal links involved. In such cases, we may say the policies which underly the decisions are implicit, or hidden. In general, the less explicit the policy, the more unrealized potential there is for its improvement.

This potential is especially striking when decisions are embedded in hidden feedback loops.[3]

The value of statistical analysis of data from management information systems in such cases is to direct managerial attention to as many such causal links as possible. Thereby, implicit policies will be made more explicit and thus susceptible to re-design.

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[2] See Wilcox [1972].

[3] See Forrester [1961].

The Costs of Uncertainty

We will take it as axiomatic that additional uncertainty induces additional costs into the performance of any task.

In addition, one may observe empirically that the longer a situation behaves as a stable process, the more opportunity one has to learn more about it, and thus, on average, the less uncertainty. On average, though not in each individual event, increased instability of the process implies increased uncertainty for the manager.

Now some instability sometimes promotes the allocation of more resources toward learning, and thus future lessening of uncertainty. The immediate effect, however, is to increase uncertainty and thus costs.

It is also apparent that quantitative changes in the environment are often not perceivable by managers as arising from a stable process. Thus such changes are typically associated with increases in uncertainty. In consequence, external changes may be taken as an indicator of increased uncertainty and thus of potentially increased costs, at least in the short run.

We can analyze changes in externally-related data recorded by the management information system as indicators of uncertainty stresses facing the organization. It may be extremely useful to locate in particular cases the major sources of this uncertainty, so that it can be reduced in the future.

Divisionalization

One can view a smoothly-running organization as a large system of local control loops dealing with localized problems. For the purposes of this paper, we will ignore the problem of motivating people to assume roles within this system. Coordination among these controls is achieved by higher-order feedback control which monitors job completion,

resource allocation, destructive internal conflict, and so on. This control
authority structure is often represented as a hierarchical tree. We will
assert that in a mature, effective organization, the authority structure will
be well matched with the uncertainty structure imposed by the task environ-
ment. Let us see what is meant by this assertion and the assumptions which
underly it.

In a mature organization, the further near-term gains from learning
will be small compared to the gains from effective utilization of the
knowledge already gained. Thus, the dominant influence will be toward
efficiency rather than innovation. In such circumstances, it will be to
the organization's advantage to keep the aggregate organizational uncertainty
low.[4]

One way to achieve lower aggregate uncertainty is to prevent the
propagation of local uncertainties to other areas of the organization. This
is done through divisionalization.[5]

The propagation of local uncertainty to other divisions can be
reduced through buffering. It can often also be thwarted through coordinating
communication and control. Empirically, we know that usually some combina-
tion of these two approaches is used. In either case, there is an argument
for divisions with potentially strong interactions of local uncertainties to
be placed directly under a common supervisory authority. First, this will reduce
coordination costs. Second, such a superior is in the best position to
make decisions on the appropriate buffers to reduce propagation of

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[4]See Emery [1969], Lawrence and Lorsch [1967], and Zannetos [1965a].
Remember that in order to keep our theory simple we are explicitly
disregarding the complications induced by motivational requirements.

[5]Divisionalization thus promotes specialization, further local learning,
and thus further local efficiencies. See Thompson [1961].

uncertainties arising in one of the two divisions.[6]

The extent of propagation of uncertainties among organizational divisions may be partly measured by the covariances in changes in divisional performance data from the management information system.[7] In this paper, we will not attempt to appraise the relative quantitative importance of such covariances; thus we will analyze correlation coefficients rather than covariances.

The pattern of covariance or correlation of uncertainties we will term the organizational uncertainty structure. Our measure of the uncertainty structure will be the pattern of correlation of year-to-year changes in accounting data. These patterns of correlation will be analyzed further through the multivariate statistical techniques of factor analysis and cluster analysis.[8]

In empirical work with this approach, it is important to remember, however, that change is an imperfect measure of uncertainty. Clearly some changes are both planned and highly predictable. Clearly, also, the costs of uncertainty are not linear functions of the quantity of change, even when change is unexpected. We use it as a measure only where no better seems to be available.[9]

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[6] In some cases this authority could be exercised through an interdivisional committee.

[7] See Zannetos [1965b]. He first proposed a similar measure for the effectiveness of divisionalization used here. He suggested accounting variances, rather than change, as the indicator of uncertainty.

[8] See Harman [1967] for a description of factor analysis. See Tryon [1970] for a description of cluster analysis. Also, ordinary multivariate regression or covariance analysis will be useful when dealing with only a few variables.

[9] Accounting variances from standard may be superior measures of uncertainty in organizations with well-developed standard cost accounting systems. Again, see Zannetos [1965b, 1968].

As previously stated, one would expect that in hierarchical organizations good divisionalization would place highly correlated disturbances under the immediate control of the same administrator. If not, there is the indication of a possibility of the fruitfulness of organizational redesign.

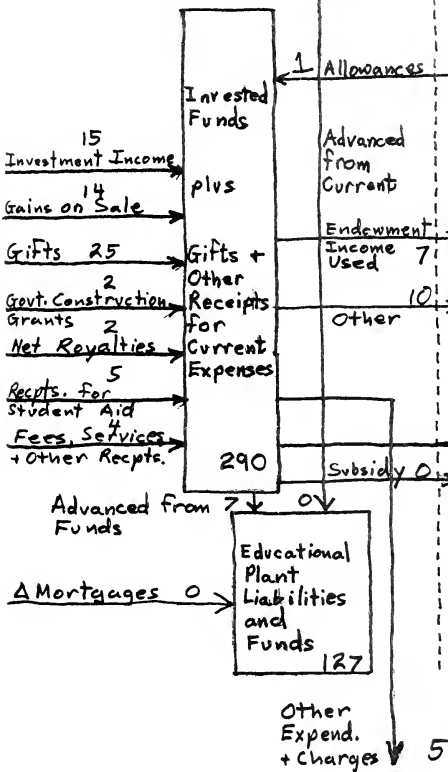Section C. Description of M.I.T. and the Available Data

The Massachusetts Institute of Technology is a private, non-sectarian institution of higher education. Its undergraduate and graduate student bodies each number approximately four thousand students. It has an inter-national reputation for research, especially applied research. In the past it has specialized in physical science and engineering. Its programs, however, have been expanding in the humanities and social sciences. In the period since World War II, it has managed several large off-campus laboratories. During the last few years it has been characterized broadly by development of new fields and departments, by a fair share of the recent student unrest, and most recently by a financial strain brought on by a decision to spin off one of the large research laboratories and by cessation of rapid growth in government-funded research.

Its total annual budget, including that for the research laboratories, exceeds two hundred million dollars.

The publicly available financial data in the M.I.T. Treasurer's report for the year 1969 is approximately represented in Figure I. The only major inaccuracies are the absences in the figure of changes in unrealized profits and losses in asset holdings and of certain pension plan operations.
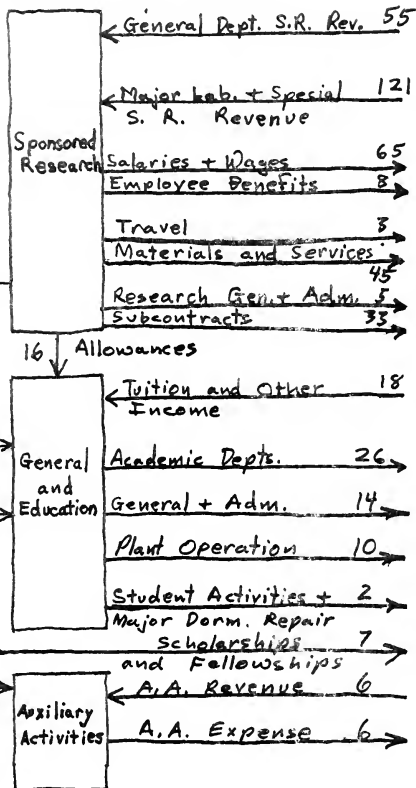
Figure I. M.I.T. Funds Flow, 1968-69

(In Millions of Dollars)

The data analyzed here are nearly all publicly available.[10] The variables used in the statistical study are listed in Figure II.

The data available are annual figures for each school year from 1950-51 through 1969-70. The consistency of reporting methods over this period is relatively good. Where changes in reporting methods have been made, they have generally been one-time changes of a type corresponding to real phenomena of interest. That is, a new, separate accounting category for a particular type of expenditure tends to correspond to a large increase in the size of that type of expenditure. The errors thus induced on statistical analysis of correlations with other variables generally tend to underestimate the extent of causal relationships.

The data have not been adjusted for changes in the value of the dollar or for changes in organizational size. The result is, in effect, a heavier weighting given to more recent observations in determining correlation coefficients.[11]

The fact that all data have been converted to first differences in order to measure changes has a beneficial result in reducing the high degree of autocorrelation in the financial time series.

There are nineteen observations of first differences in each of the variables. We also have available data from the registrar's report regarding numbers of students.

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[10] The only exception is a four-part breakdown of sponsored research revenue not publicly reported during the first ten years of the period under study.

[11] This causes some heteroscedasticity. Regression analyses based on these figures are thus unbiased but are slightly less reliable than standard t-tests, etc. would indicate. See Johnston [1963]. The test of significance for factor eigenvalues reported later is also influenced.

Figure II. Major Variables from Treasurer's Report

(slightly revised from Figure I)

Inflows	Outflows

Funds

Investment Income
Gifts
Royalties Net of Related Costs
Receipts for Student Aid
Net Gain on Sales
Government Construction Grants
Fees, Services and Other Receipts

Scholarship and Fellowship
  Awards for Tuition and Stipends
Expenditures of Service Activities
  and Other Charges to Funds not
  Representing Operating Expenses

Academic

Tuition Income and Other
Auxiliary Activities

Academic Departments
General and Administration
Student Activities, General
  and Plant Expenses and Major
  Dormitory Repairs
Plant Operations
Auxiliary Activities

Sponsored Research

General Departmental and
  Interdepartmental Research Revenues
Lincoln Laboratory Revenues
Instrumentation Laboratory Revenues
Other Research Revenues

Salaries and Wages
Pension and Other Employee Benefits
Material and Services
Subcontracts
Travel
Research General and
  Administrative Expenses

Other Liabilities and Funds

Increases in Accounts Payable and
  Accruals
Increases in Withholdings, Deposits
  and Other Credits
Increases in Advances by U.S. Government
  for Sponsored Research
Increases in Unexpended Grants for
  Sponsored Research from Private
  Sources
Increases in Mortgage Bonds and Notes
  Payable

*Increases in Mortgage Bonds
  and Notes Payable
*Increases in Investment Funds Used
  for Educational Plant
*Increases in Advances from Current
  Funds to Educational Plant

*These increases primarily reflect expenditures for new buildings.

Section D. Factor Analysis of Treasurer's Report Variables

The financial accounting variables chosen for analysis represent a relatively clean partition of the receipts and expenditures of M.I.T. They are based on major headings in the Treasurer's Report. These were shown in Figure II. A factor analysis of simultaneous year-to-year changes in these variables gives some indication of the short-term interrelationships among the uncertainties associated with them. Unfortunately, there is insufficient data to thoroughly investigate lagged relationships among these uncertainties.

Factor Analysis of Annual Changes in Major Financial Variables

The year-to-year changes in the variables of Figure II were factor analyzed using a varimax rotation of principal components.[12]

The factor structure obtained is shown in Figure III. The coefficients at the left represent the correlation of the constructed factor with the variables. The eigenvalue, E, of the factor divided by the number of variables, n, gives the proportion of normalized variance in the sample accounted for by the factor. The eigenvalues of Factors I, II, III, and IV were estimated to be too large to arise purely by chance.[13]

Of course, these factors merely conveniently summarize the data sample being analyzed. At this stage, they do not deserve to be termed a "model."

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[12]See Harman [1967] for a more detailed description of the procedure used.

[13]The test was based on the estimated mean and standard deviation of eigenvalues derived from a Monte Carlo simulation. The test checks whether the jth largest eigenvalue is greater than 3 times the estimated standard deviation from the estimated mean of the jth largest eigenvalue derived from pseudo-random data. Factor V was also indicated as significant by the test but was rejected when the possible effects of heteroscedasticity were taken into account.

Figure III

Varimax Rotated Factors in Year-to-Year Changes in Treasurer's Report

Factor I, E = 4.95, n = 32

.76   Investment Income

.78   Scholarships and Fellowship Awards

.84   Academic Department Expense

.74   Plant Operation

.83   Auxiliary Activities

.61   General Departmental and Interdepartmental Research Revenue

Factor II, E = 4.86, n = 32

.96   Royalties Net of Related Costs

.88   Expenditure of Service Activities and Other Charges to

      Funds Not Representing Operating Expenses

.84   Student Activities, General and Plant Expenses and Major

      Dormitory Repairs

.64 Δ Advanced from Current Funds for Educational Plant

Factor III, E = 4.91, n = 32

.71   Government Construction Grants

.80   Sponsored Research Materials and Services

.70   Sponsored Research Subcontracts

.76   Instrumentation Lab. Revenue

.74 Δ Investment Funds Used for Educational Plant

Factor IV, E = 3.54, n = 32

.78   Net Gain on Sales of Investments

.77   Fees, Services and Other Receipts*

-.71   ΔMortgage Bonds and Notes Payable

.62   Gifts

*In the period 1950-59, this category includes net gain on sales of investments.

Figure III, (continued)

However, if we find them to be related to causal variables of interest, we may well use them as important components of such a model. In any case, as Herzberg has shown, they may be useful in deriving robust small-sample regression equations for predicting individual variables.[14]

Speculative Discussion of the Factors

The following discussion may be of some interest to university participants. It is tentative and conjectural in nature. It was written prior to the cluster analysis of the next section.

Factor I

The correlation of investment income with scholarship and fellowship awards, academic departmental expense, plant operation, auxiliary activities (including student housing, dining, and the university press) and on-campus sponsored research may represent an expression of the most basic organizational functions. Presumably the investment income from endowment has the fewest external demands associated with it of any source of funds. We see that those categories which are associated with such income correspond fairly well with our notions of the basic functions of universities. The correlation with corresponding changes in the on-campus sponsored research revenues may even testify to some complementarities between teaching and research.

Factor II

This factor is harder to interpret. It is strongly influenced by a one-time spike in royalties in 1963. It may be a statistical artifact combining two or three clusters of changes. The following remarks are the result of inspecting smaller correlations of variables with the factor.

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[14] See Herzberg [1969].

In one conceptual cluster there appears a kind of lagged sponsored research component which includes royalties, sponsored research pensions and other employee benefits, and changes in the liability of unexpended private research grants. Another conceptual cluster seems to bear on student activities and on university services to alumni and the community.[15]

Factor III

This factor exhibits major aspects of M.I.T.'s off-campus sponsored research, most of which is done for the government. It is noteworthy that these activities are mostly independent of on-campus activities at the same point in time with the interesting exception of on-campus government construction grants and changes in investment funds used for capital expenditures on the campus educational plant. This indicates a possible short-term influence of off-campus research activity through building programs. The latter clearly also will have long-term, lagged implications in terms of academic activities. The lack of other correlations among the simultaneous year-to-year changes does not rule out the existence of other, _lagged_, causal relations between off-campus laboratory and on-campus activities.

Factor IV

Another major external driving force on the university is apparent in this factor. A check on stock market history indicates that its fluctuations have not only a direct effect on net gain on sales of investments but an apparent indirect effect on gifts. When these sources of funds are not available, new educational plant may be financed by mortgage bonds (or even advances from current liabilities--their correlation with Factor IV was -.52).

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[15]The cluster analysis in the next section will show that these conceptual clusters correspond to statistical clusters also.

The Broad Picture Provided by the Treasurer's Report Factor Analysis

The inter-relationships among the factors is made more apparent by the time-series of the factor scores through this period. An appropriate context in which to view these time-series is to think of them as representing planned or unplanned disturbances to the organization's on-going routine. Along with what we know about the pattern of enrollments this context suggests some interesting hypotheses. In Figure IV, we have charted the factor scores of Factors I and III. In Figure V, Factors II and IV are shown.

The most obvious feature of these figures is that recent year-to-year changes in both expenditures and receipts are bigger than earlier ones. However, this is an artifact of the fact that the factor analysis was based on data unadjusted for changes in organizational size or in the value of the dollar.

Signals of Possible Propagation of Uncertainty

We assume that large year-to-year changes in treasurer's report items correspond not only to uncertainty but also to stress. Of course, we cannot tell from the data whether the changes were planned or unplanned. If unplanned, we cannot be sure whether they arose from the environment or whether they arose internally.

The hypothesis most plausible to the writer is that the changes arose under the influence of external events. The internal responsibility for those disturbances would lie mainly therefore in the manner or mechanism through which the organization characteristically responded to events. Some of these mechanisms are suggested by the patterns of relationship among changes in the various categories of data.

Figure IV seems to indicate that after a lag of two to three years, changes in off-campus research revenues are transmitted to changes in basic
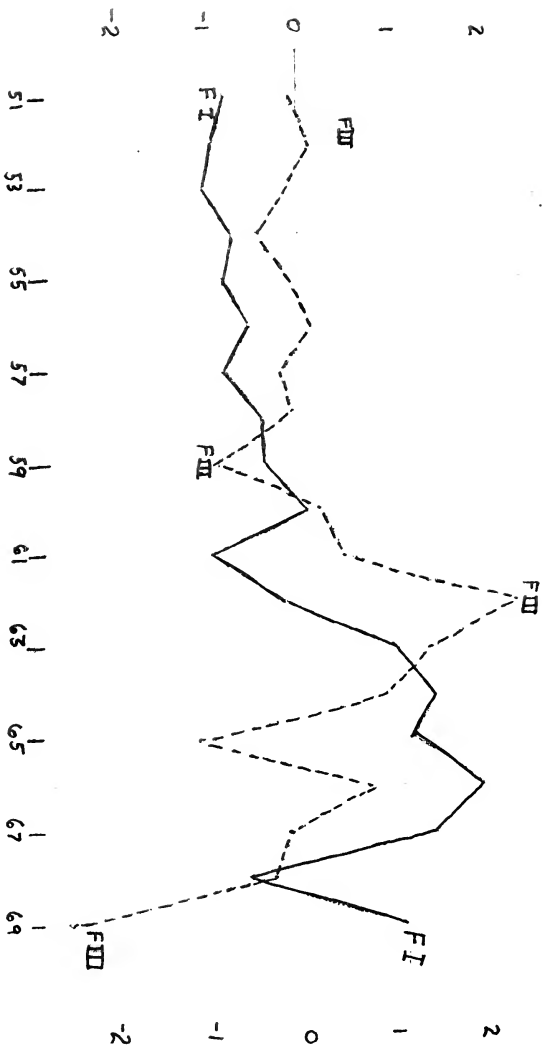
Figure IV. Factor Scores from M.I.T.
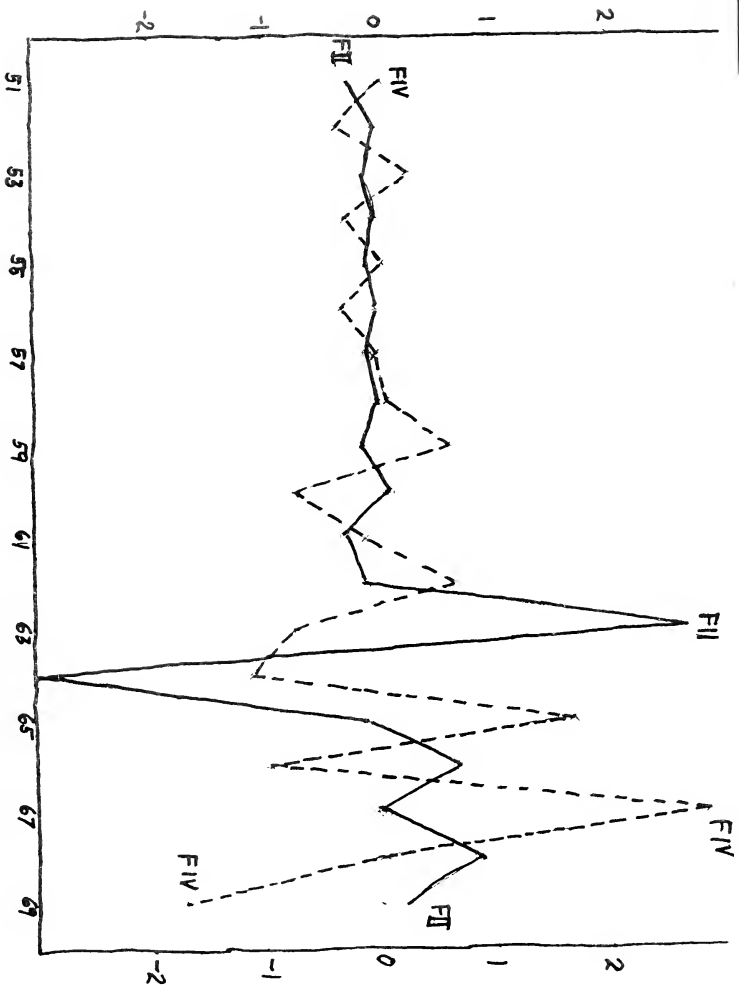Treasurer's Report

Figure V. Further Factor Scores From M.I.T.
Treasurer's Report

on-campus activities.[16] Several possible mechanisms suggest themselves.

First, funds are made available to endowment, and thus later investment

income, through appropriations from contract research and indirectly through

overhead recovery. Second, there is the possible stimulus of new buildings

financed in association with revenues from sponsored research which later

influence in a complex way the expansion of academic budgets. An additional

link might be through the financing of advanced graduate students and research-

oriented faculty. That is, increases in sponsored research off-campus

might conceivably lead to increases in enrollment of graduate students or

even the hiring or promotion of faculty and consequent potential increases

in later academic department expenditures. In any case, the evidence suggests

that immediate effects are not as important as sources of organization dis-

turbances as are possible longer-term effects.

Of course, a complementary explanation of the relationship between

Factors III and I which does not involve the propagation of uncertainty puts

both as consequences of a third outside influence, the post-Sputnik federal

government activity in support of technology. This influenced both increased

R & D and increased support to graduate education. The analysis of Registrar's

data regarding student enrollment for this period will enable us to better

judge the strength of this outside, "coincidental" relationship between Factor

III and Factor I.

Another possible outside third influence is the association of stock-

market-driven funds used for new building with sponsored research revenues.

It may be that for various reasons the Institute's portfolio gains are correlated

with increases in off-campus sponsored research.

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[16]Part of this lagged relationship was estimated at $FI_t = .004 + (.57)FIII_{t-2}$,
$R^2 = .21$, sig. at the 10 per cent level unadjusted for heteroscedasticity or
any non-normality. Of course, an alternative non-causal explanation is that
changes in both variables are caused by the same exogeneous variable.

Figure VI shows year-to-year changes in the number of graduate students. For purposes of comparison, these data have been normalized by subtracting their mean and dividing by their sample standard deviation. Let us relate Figure IV and Figure VI. The latter shows dramatic fluctuations of year-to-year changes in graduate students in the period 1953-57. Figure IV, however, shows very small fluctuations during that period in the Treasurer's Report Factor I, which was associated with academic departmental expense. The fluctuations in change rates of graduate students during the period 1961 through 1965 were of the same order of magnitude as before, but were accompanied by very much larger changes in academic departmental expense. This might be thought to reflect more intensive use of graduate students in teaching assistant positions. However, a check showed that the ratio of teaching assistants to graduate students has remained roughly constant throughout the nineteen year observation period. Also, it is doubtful that the ratio of teaching assistant salaries to faculty salaries has increased. Thus, one is led toward the conclusion that the correspondence suggested in Figure IV between large changes in Treasurer's Report FIII and FI two or three years later is largely unexplainable in terms of coincidental influxes of graduate students.

Although the evidence is not conclusive, it is hard to escape the notion that the observed relationship between changes in off-campus sponsored research activities and lagged changes in academic departmental expenses is probably endogeneous to the organization and causal in nature. That is, apparently the organization has responded to fluctuations in off-campus research revenues or associated portfolio gains in such a way as to propagate them in the on-campus activities several years later. The exact mechanisms, however, are still undetermined.
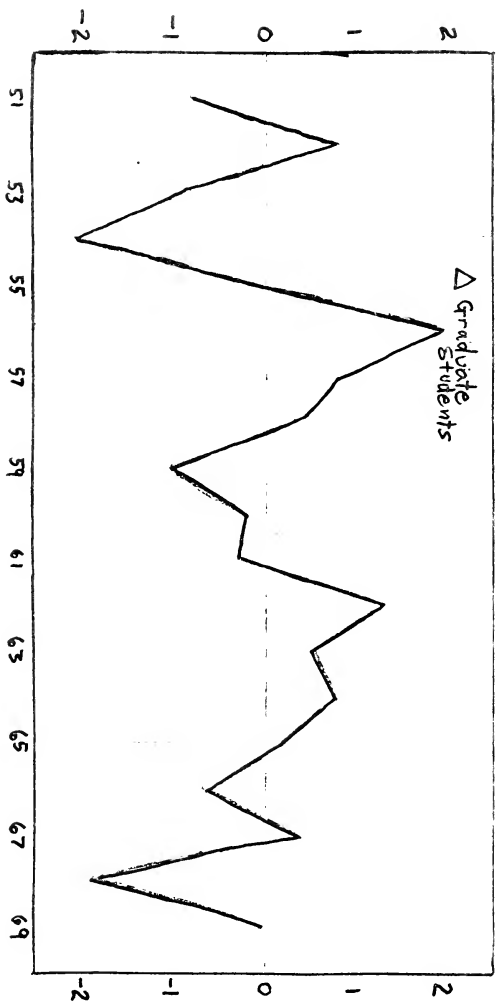
Figure VI. Normalized Changes in M.I.T.

Graduate Students

The primary external sources of disturbance revealed by the data
of this section are:

1. variations is sponsored research revenue

2. variations in the stock market

3. variations in enrollment.

The simple correlations observed may be fruitful indicators to the
university administration of the propagation of these disturbances throughout
the structure of the organization.

Section E. Cluster Analysis of Treasurer's Report Data

The procedure used for cluster analysis of year-to-year changes was
McQuitty's "iterative, intercolumnar correlational analysis".[17] This method
builds a hierarchical tree from the top down in which variables on nearby
branches are highly correlated. Such methods have been useful in establishing
initial taxonomies of classification in fields such as anthropology and
comparative biology. The particular procedure used struck the writer as
somewhat analogous to the normative procedure of divisionalization noted
earlier in Section B. At the least, it seemed to merit a trial. Unfortunately,
the statistical sampling properties of this procedure are not yet established.[18]
Unless testable against other data, its result is therefore useful mainly
as a heuristic adjunct to factor analysis and regression. Thus, the following
discussion is presented in a tentative and experimental spirit.

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[17]See McQuitty and Clark [1968].

[18]This does not mean that its output cannot be tested against new data.
For example, one could test for a non-random relationship between two
trees by first rotating their branches for maximum congruence and then
calculating the Kendall tau coefficient of rank correlation. Ideally,
this method could be used to test the null hypothesis of no relationship
between an authority structure and an uncertainty structure.

A matrix of intercorrelations of the year-to-year changes in the
Treasurer's Report variables listed in Figure III was calculated. A new
matrix of the absolute values of these correlation coefficients was formed,
since it was not intended to distinguish between positive and negative rela-
tionships. This second matrix was analyzed for clusters using McQuitty's
iterative, intercolumnar correlational analysis.

This procedure operates approximately as follows. At the top level,
all variables are regarded as part of the same cluster. This cluster is
then fragmented into sub-clusters by recursively correlating the column data
of the original correlation matrix. This process converges to a matrix of
plus and minus ones. All the variables of each sub-cluster are inter-associated
by plus ones in the appropriate off-diagonal entries in the asymptotic matrix.
After the sub-clusters are formed, they are each in turn subdivided through
the same process. The procedure ends when all clusters have been fragmented
to single variables. The hierarchical tree thus obtained from the Treasurer's
Report data is presented in Figure VII.[19]

The results are interesting. In very broad outline, the hierarchical
tree of Figure IX, which is intended to represent the uncertainty structure,
is reminiscent of the formal authority structure of M.I.T. Using the listings
of administrative officers and their titles in the 1962-63 M.I.T. catalogue,
one derives such an authority structure -- see Figure VIII.[20]

Without extensive reference to historical records and interviews, it is

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[19] A listing of the author's Fortran computer program for this procedure may
be obtained on request.

[20] Parenthetically, of course, a further drawback of the analysis is the lack
of inclusion of lagged relationships. The limited data did not appear to
justify investigating even the one-year lags, because this would have reduced
the number of observations to 18 and increased the number of variables to 64.

somewhat difficult to map responsibility for each of the Treasurer's Report variables into the list of officers on Figure VII. Thus, the formal testing of the hypothesis of a non-random relationship between the authority structure and the uncertainty structure was left for a further study. However, the hierarchical tree derived through cluster analysis of our measure of uncertainty appears intuitively to have some correspondence with the organizational authority structure.[21] For example, sponsored research revenues and expenditures are almost all in Cluster C22. Most of the funds transactions associated with the treasurer are in Cluster C12. Instructional expenses, student aid, and auxiliary activities, including dormitory and dining facility expenses, are together in Cluster C11, thus grouping the academic departments and the so-called academic offices. An interesting confirming result is the association in C22 of fees, services and other receipts to funds with various sponsored research activities. Looking at the organization chart, one finds that in 1963 the Vice President of Research Administration (on campus) was also charged with the industrial liaison office and the summer session, which give rise to these receipts.

Speculative Discussion of Cluster Anomalies

On the other hand, there are some curious exceptions to the overall congruence of the cluster analysis tree with the organizational chart. What may be the reasons? First, as the reader may note, at the higher levels the writer was not sure even of the authority structure. Second, some of these exceptions no doubt reflect errors of measurement. Some, however, may reflect genuine incongruity of the true authority structure with the true uncertainty structure. This would imply potential disequilibria between the

[21] Again, however, this appearance may be deceptive. We must wait for more evidence before making a final judgment.

Investment Income
Auxiliary Activities

Receipts for Student Aid
Scholarship + Fellowship Awards

Academic Departments
Plant Operation

Research Gen. + Admin. Exp.

Gifts
Δ Advanced f. Current for
   Educational Plant
Δ Accounts Payable
Δ Mortgage Bonds + Notes Pay.

Tuition Income + Other
Δ Advances by U.S. for Sp. Res.

Δ Withholdings, etc.

C11

C12

C1

C
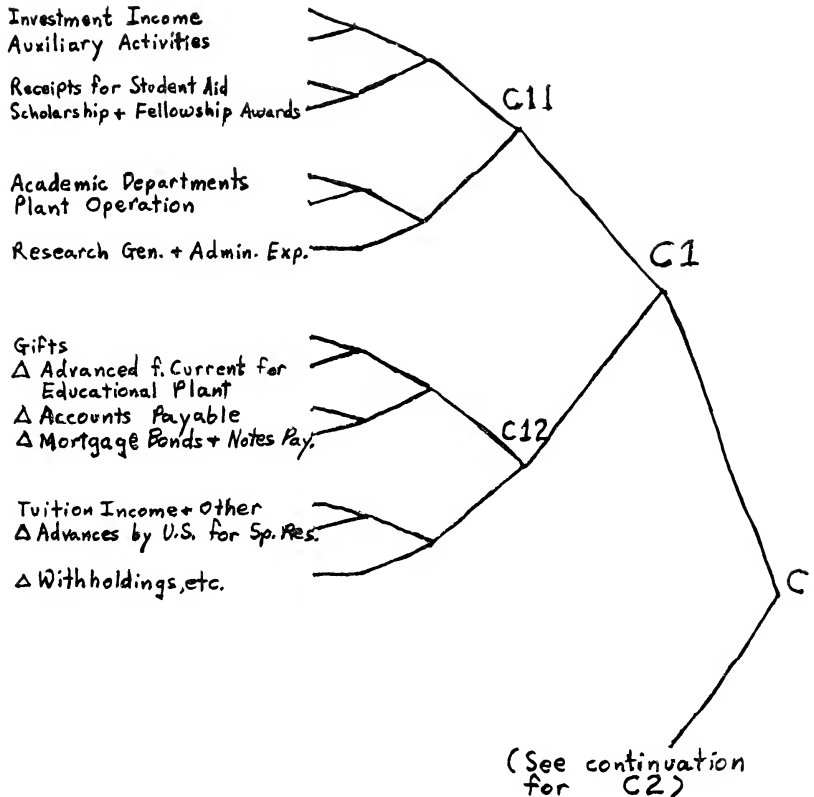
Figure VII. Cluster Analysis of M.I.T. Treasurer's Report

Royalties
Exp. of Service Activities + Other Charges to Funds
Student Activities + Major Dorm. Repairs
General + Administration
S.R. Pension + Employee Ben.
Δ Advances f. Private S.R.
C21

(to C)
C2

Net Gain on Sales
Sponsored Res. Subcontracts
Fees, Services, + O. Receipts
Sp. Res. Travel
C221

C22

Govt. Construction Grants
Instr. Lab. Revenue Advanced f. Funds for Educational Plant
Gen. Dept. + Interdept. S.R. Revenue
Spon. Res. Salaries + Wages
C222

Sp.R. Materials + Services
Lincoln Lab. Revenue
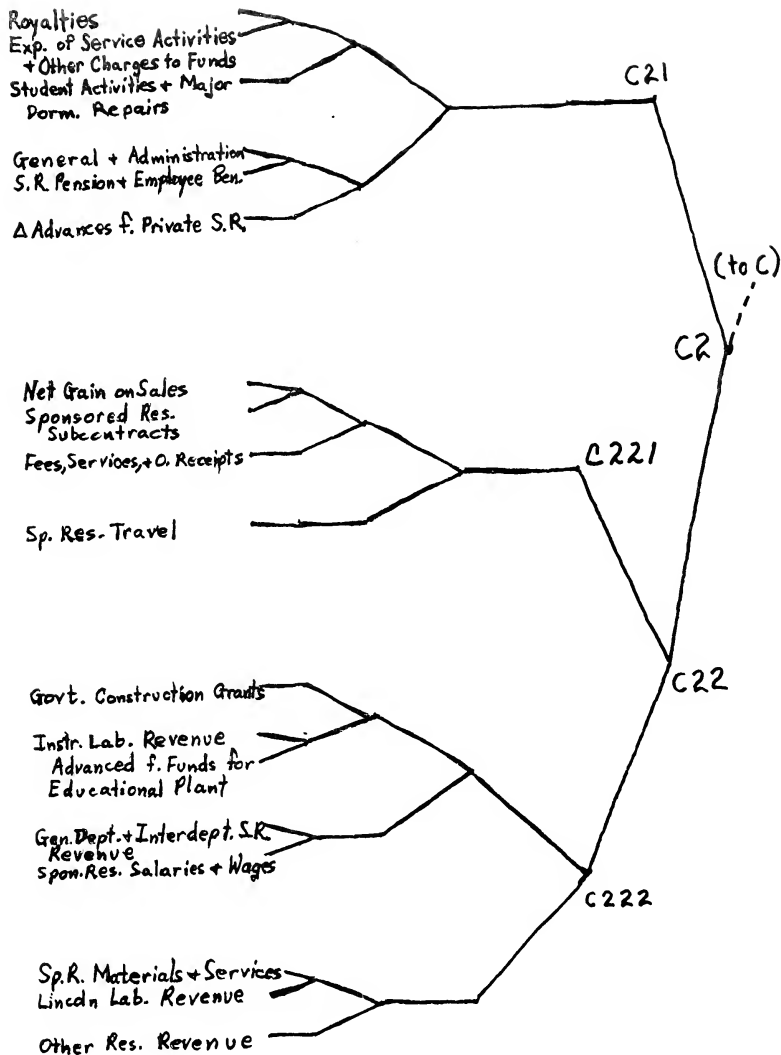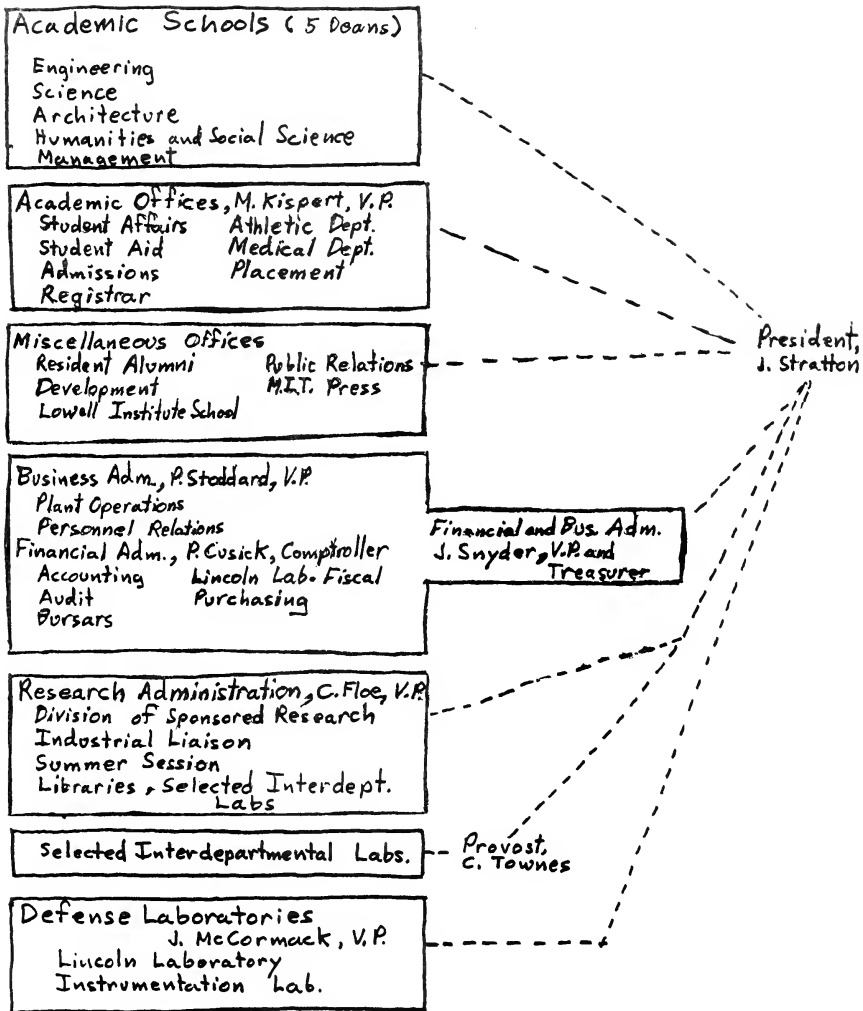Other Res. Revenue

Figure VII (Continued).

Figure VIII. M.I.T. Administration as per 1963 Annual Report and Catalogue

authority structure and the uncertainty structure which we may profitably analyze. Among the most apparent anomalies are:

1. Investment Income in C11

2. Plant Operation in C11

3. Research General & Adm. in C11

4. Royalties in C21

5. S. R. Pension in C21

6. ΔAdvances Private Sponsored Research in C21

7. Net Gain on Sales in C221

8. ΔAdvances From Investment Funds for Educational Plant in C222.

If the theory of determinants of divisionalization noted in Section B were valid, if our measures of uncertainty structure and corresponding authority structure were valid, and if the anomalies noted above were not simply sampling errors, one could draw the following normative conclusion. These anomalies should be reduced either through an alteration in authority structure or through an alteration of the uncertainty structure (perhaps through adding buffers, etc.). Furthermore, we may also descriptively predict some movement in this direction. Let us for the exercise, proceed to provisionally draw such conclusions and see to what hypotheses they lead.

The inclusion of investment income and plant operation in C11 along with expenditures for academic departments, scholarships, student housing, and so on, probably reflects relatively fixed inter-correlations of year-to-year changes and thus uncertainty among the variables.

Correlation	Variable
.64	Plant Operation
.70	Investment Income

Correlation with Academic Department Expense

This suggests the possibility that the authority structure should change so as to place more coordinative controls over the variables in this cluster. One way to accomplish this would be to delegate more responsibility, and provide more information, to the deans of the academic schools regarding the their plant operation expenses and regarding their endowments.

The author is not aware of the necessary fixities placing research general and administration expenses in C11. There are no strong correlations of this variable with any other single variable in the Treasurer's Report. Even the correlation with other C11 variables is modest:

Correlation	Variable
.43	Academic Depts.
.36	Plant Operation
.18	Investment Income
.39	Auxiliary Activities

Correlation with Research General Administration Expenses

The interaction may be a statistical artifact or it may be a result of the inclusion of certain general administrative duties in the charge of the V.P. for Research. In the latter case it may or may not be desirable, but it is not an anomaly as we have defined it.

The next anomalies show a remarkably coherent and logical pattern. The changes in ΔAdvances for Private Sponsored Research, Royalties, and Sponsored Research Pension and Other Employee Benefits, which are closely associated through time with sponsored research activities, are associated on a simultaneous year-to-year basis with various superficially unrelated administrative expenditures.

Correlation	Variable
-.77	S. R. Pension, etc.
.61	ΔAdvances for Private S. R.

Correlation with General Administration

Apparently, advance payments for private sponsored research influence immediate increases in administration expenses, or vice versa. After a lag, these advances are used up as the work is performed and as S. R. employee benefits increase. This decrease in funds seems to influence a decrease in administrative expenditures. If a causal relationship from administrative expenses to increases in advances for private sponsored research underlies the observed correlation, we have evidence for the existence of an unsuspected negative feedback loop.

The link of royalties, a lagged effect of sponsored research, with expenditures of service activities and for student activities, etc., is similar. However, in this case, there is less reason to suspect feedback.

Correlation	Variable
.83	Expenditures of Service Activities
.77	Student Activities and Major Dorm. Repairs

Correlation with Royalties

Because of time lag effects, there is a natural negative correlation (-.63) between royalties and ΔAdvances in Private S. R. Thus, both these apparent funding arrangements appear together in C21.

All together, these anomalies in C21 suggest one of two needs. Either one should buffer the expenditures for service activities, student activities, and general and administration from fund flows related to sponsored research, thus changing the uncertainty structure, or else, one should change the authority structure so that more of the covariances in the pattern of

uncertainty be placed under the coordinative control of a single administrator. In this case, the first course seems wiser, since there do not seem to be very strong inherent complementarities.

The next anomaly is the inclusion of net gain on sales in C221. We have the following correlation matrix of year-to-year changes.

	1	2	3
1	1.00	.75	.44
2		1.00	.37
3			1.00

Correlation Matrix of:

1. Net Gain on Sales of Investments

2. Sponsored Research Subcontracts

3. Fees, Services and Other Receipts

Thus, there is some evidence that net gain on sales of investments are associated at the same point in time with the need to subcontract, presumably when in-house sponsored research capacity is filled. There is also a correlation with fees, services, and other receipts, which includes funding from industry. C221 is a sub-cluster of C22, which includes the remaining sponsored research activities. For example, consider the following correlation with the most applications-oriented source of sponsored research revenue.

Correlation	Variable
.44	Instrumentation Lab. Revenue

Correlation with Net Gain on Sales of Investments

We see a small but interesting positive correlation of net gain on sales of investments with the revenues from the Instrumentation Laboratory.

It is unlikely that there is an inherent internal positive causal relationship between gains from sales of investments and revenues

from M.I.T.'s applied research and development and fees, services, and other
receipts. The most important determinant of M.I.T.'s realized gains is the
performance of its investments. Thus, one suspects that the performance of
M.I.T.'s investment portfolio is correlated to some extent with changes in
its revenues for applied research and development and with fees from
industry. Since it is hard to imagine an intrinsic complementarity here, the
normative implication is that the uncertainty structure should be changed
to buffer net gain on sales of investments from research and industrial
service activities. This could be done through a change in portfolio
policy toward holding fewer securities whose performance correlates with U.S.
government support for applied research and development. Another possibility
is to reduce M.I.T.'s dependence on applied research revenues which correlate
with the performance of the securities markets and with the business cycle.

Finally, let us consider the anomaly of the placement of changes in
advances from investment funds for educational plant in C222, the heart of
the sponsored research clusters. Consider the following correlations.

Correlation	Variable
.76	Instrumentation Lab. Revenue
.62	Government Construction Grants
.45	General Dept. and Interdept. S. R. Revenue

Correlation with ΔAdvanced from Investment Funds for Educational Plant

Government construction grants are positively correlated with increases
in Instrumentation Lab. Revenues. It is apparent that off-campus sponsored
research is associated, at least indirectly, with on-campus building programs.
Such building imposes a fixed overhead which has long-term effects on plant
operations. There may be more subtle effects on academic departmental expenses
because of the tendency to expand operations to fill the building space. The

normative implication is to reduce the interactions between sponsored research and new on-campus building.

In summary, we located anomalies through a comparison of the authority structure with the uncertainty structure indicated by cluster analysis of year-to-year changes. These anomalies were used to generate normative prescriptions as to changes in either the uncertainty structure or the authority structure. Now let us consider whether these anomalies have any use as generators of hypotheses as to descriptive predictions. The evidence is probably too scanty without a more extensive study of the authority structure to permit rigorous testing as per footnote 12. However, we may obtain some heuristic insights through an examination of the new organizational authority structure of 1971 taken from the catalogue and shown in Figure IX.

In one case, we did prescribe a change in authority structure. This was a change to better coordinate uncertainties in plant operation and investment income with those of academic departmental expense. Plant operation, it happened, was taken out of the treasurer's sphere by 1971. A major new administrative post, that of Chancellor, was created to take responsibility for much of the coordination associated with the academic departments. We can not tell without further data whether the effect was to increase the possibilities for administrative coordination of academic departmental expenditures, plant operation, and investment income. However, one such item of data might be the recent experimentation with a new budget information system designed to give the deans of the academic schools much more information regarding the total expenditures and receipts associated with their activities, including plant operation. Also, at least one of the academic deans has begun monitoring closely his own segregated endowment funds. Of course, this does not imply that these steps are the most appropriate moves toward additional coordination.

Our evidence, however, may give us some understanding of their motivation,
however wise or misguided.

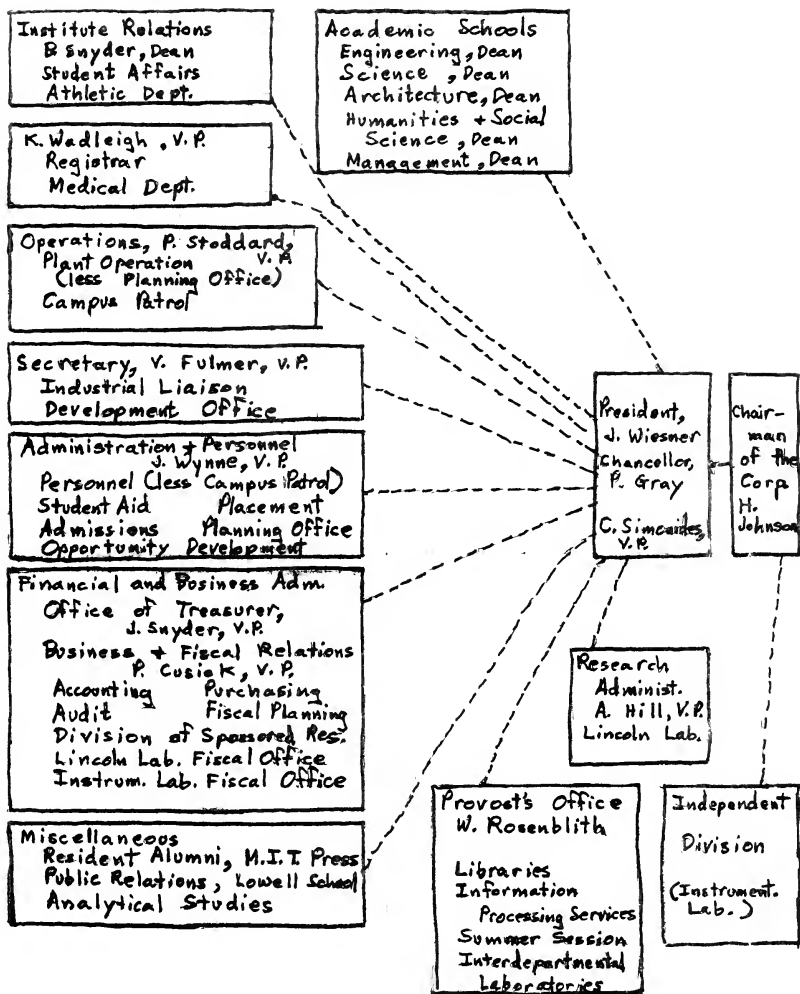In the case of our prescription for changes in the uncertainty structure,

Figure IX. M.I.T. Administration 1971

Institute Relations
  B Snyder, Dean
  Student Affairs
  Athletic Dept.

Academic Schools
  Engineering, Dean
  Science, Dean
  Architecture, Dean
  Humanities + Social
    Science, Dean
  Management, Dean

K. Wadleigh, V.P.
  Registrar
  Medical Dept.

Operations, P. Stoddard,
  Plant Operation   V. P
    (less Planning Office)
  Campus Patrol

Secretary, V. Fulmer, V.P.
  Industrial Liaison
  Development Office

Administration + Personnel
    J. Wynne, V.P.
  Personnel (less Campus Patrol)
  Student Aid   Placement
  Admissions   Planning Office
  Opportunity Development

Financial and Business Adm.
  Office of Treasurer,
    J. Snyder, V.P.
  Business + Fiscal Relations
    P. Cusick, V.P.
  Accounting   Purchasing
  Audit   Fiscal Planning
  Division of Sponsored Res.
  Lincoln Lab. Fiscal Office
  Instrum. Lab. Fiscal Office

Miscellaneous
  Resident Alumni, M.I.T Press,
  Public Relations, Lowell School
  Analytical Studies

President,
J. Wiesner
Chancellor,
P. Gray

C. Simonides
V. P.

Chair-
man
of the
Corp
H. Johnson

Research
Administ.
A. Hill, V.P.
Lincoln Lab.

Provost's Office
W. Rosenblith

Libraries
Information
  Processing Services
Summer Session
Interdepartmental
  Laboratories

Independent
Division
(Instrument.
Lab.)

there is too little data available to give us much insight into the

strength of our hypotheses. Several further caveats may be in order. First,

the changes in authority structure seemed to be influenced by changing per-

sonalities and career patterns at the top layers of the administration which

could not easily be predicted by our primitive theory. Second, a decision

was made to spin off the Instrumentation Laboratory (as the Draper Laboratory).

This decision was ostensibly made for non-financial reasons. Fortuitously

or not, it seems likely to simplify the uncertainty structure through reducing

the links of sponsored research with building of educational plant, and with

various other on-campus uses of research-related funds.

Section F. Summary and Conclusion

A major motivation of this study was to find out more about the

extent to which organizational policy and structure questions could be answered

through statistical analysis of accounting data. Perhaps the reader will

agree that in our M.I.T. example we gained a better understanding of the role

of existing implicit policy in propagating disturbances. As new sources

of observations on M.I.T. and similar organizations are analyzed, the additional

statistical degrees of freedom will make it possible to narrow-in on a few

key relationships. Thus, in future studies of these organizations, it will

be practicable to use ordinary multivariate regression methods rather than

factor analysis.

A second major aspect of this study was an attempt to construct from

accounting data a hierarchical uncertainty structure for the organization

and to relate it to the authority structure. This appeared to have some

potential for success. It was not possible to test strictly that potential in the case of M.I.T., however, without more extensive empirical investigation of the authority structure and its mapping into the accounting data. This problem would be presumably less severe in a business firm.

Even if good authority structure information had been available, however, there remain important areas for possible improvement of the measurement methods used.

Our use of the cluster analysis of year-to-year changes in accounting variables as a measure of the uncertainty structure has not been investigated thoroughly. To what extent does change correlate with uncertainty costs? Also, it may be that lagged relationships must also be included to get a reasonable indicator of coordination needs.

We have analyzed authority structure as determined by uncertainty structure. Unfortunately, the uncertainty structure is also in part determined by the authority structure. Thus, our method clusters authority-induced patterns in year-to-year changes whether or not these conform in pattern to the real requirements of the task situation. That is, it cannot separate authority-induced from task-induced ingredients in the uncertainty structure.

Despite all these difficulties, the problems at stake are sufficiently important so that even the modest progress demonstrated here may have important implications for policy-makers.

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